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Otitis Media and Cognitive Development: Theoretical Perspectives

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This paper explores the theoretical positions underlying predictions that the hearing loss associated with otitis media affects cognitive and language development. The relationship between sensory input and higher mental processes has been the topic of a long-standing theoretical debate in the fields of psychology and philosophy. Our current interest in theory is more than academic; researchers or clinicians make predictions about the effects of otitis media as a function of the theory of development they hold, implicitly or explicitly.

In this paper we will discuss three current classes of theories of cognitive development. All assume that cognitive development is a function of experience and all assume that the absence of experience has deleterious effects.[1] Yet, they differ in their assumptions about the nature and role of experience, the effects of disruptions of sensory input, and the mechanisms mediating those effects. There is a growing sense in the field of developmental psychology that the most satisfying overriding theory is one in which the infant is born with a biological endowment that organizes sensory experience and that shapes learning about language and certain kinds of concepts. In this view, the

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[1] An excellent discussion of the role of experience in different developmental theories can be found in Gottlieb (1983). This would be a valuable reference for researchers or clinicians who desire a more general review of the issues.

infant actively searches the environment for experiences that will support this learning. Since this position is less familiar in otitis media research, we will review it in more detail than the other two positions and will discuss research designs suggested by it.

Definitions and Assumptions

Cognitive development involves the acquisition of knowledge about the world and the development of devices for processing that knowledge. The field includes the development of concepts such as number and causality and the development of processes such as memory and language. The task of the developmental psychologist is to discover the principles of acquisition: the sequence of changes, mechanisms of acquisition, and functions of new knowledge and new reasoning devices. In studying the effects of otitis media on cognitive development, we are interested in more than describing outcomes. We are also interested in how otitis media might influence the developmental sequence, whether similar outcomes might be preceded by different developmental sequences, whether different outcomes can follow the same illness, and which factors might influence development favorably or unfavorably during periods of illness and good health.

In reviewing studies on developmental effects of otitis media we make several basic assumptions. The first is that although we may call the condition simply "otitis media," we are referring to a history of chronic or recurrent bouts of symptomatic or asymptomatic effusion with resulting intermittent, variable, mild to moderate hearing loss (Bluestone et al. 1983). We assume that, unless otherwise stated, studies are restricted to the pure cases, where the only thing wrong with the subjects is a history of otitis media. Chronic otitis media is associated with Down syndrome, cleft palate, and possibly with subtle unrecognized CNS disorders (Paradise 1981), conditions which themselves are associated with poor developmental outcome. It is important to rule out the possibility that other factors, such as these medical conditions, mediate reported consequences of otitis media. We acknowledge that there are many possible explanations for an association of otitis media and developmental sequelae (Leviton 1980 and this volume; Paradise 1981). We will concentrate only on the hypothesis that otitis media compromises hearing acuity which in turn compromises cognitive and language development.

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Developmental Theories

The Empiricist Theory

The Empiricist position, simply stated, is that all knowledge comes in through the senses and is built up by our capacity to form associations. The infant's mind is characterized as a blank slate, upon which will be written the record of her sensory and association history. It is a mind that has no initial capacity to interpret, select, or organize incoming data. The infant's world is a set of fragmentary sensory data.

There are several corollaries to the basic position. First, the greater the degree of sensory input, the greater the opportunity to build associations and thus, the greater the degree of knowledge about objects of the world. Second, the greater the diversity of sensory data, the greater the opportunity to build associations representing objects and the greater the understanding of objects in the world. Objects have sounds as well as sights and smells, and our understanding of these objects must integrate all of the sensory modalities.

The predicted consequences of an Empiricist theory for the effects of low level hearing loss are straightforward. Even limited hearing loss should have a definite negative impact on the course of cognitive development. The decrement in auditory information decreases the amount and the diversity of sensory experience and thus the amount of knowledge about objects in the world. Sensory deprivation may influence any and all types of cognition. If the infant's mind is a *tabula rasa*, without structures to determine differential developmental patterns in different domains, then the effects of a specific deprivation such as hearing loss may be nonspecific, apparent in multiple areas.

The Critical Period Theory

Critical Period theory differs from the Empiricist view in that the infant's mind is not a blank slate. The child is created with a biological endowment, albeit an immature one, which allows for the selection of complex, organized sensory data for input to specific processing mechanisms. It is assumed that the child is maximally sensitive to this stimulation at a particular point in the life cycle, and that exposure to the requisite sensory data must occur if normal development of the underlying processing mechanisms is to occur. In its strongest interpretation, specific experiences must occur during a critical time; otherwise, there will be irreversible damage to physiological mechanisms and the behaviors of interest. In a weaker inter-

pretation of the theory, there are Optimum or Sensitive rather than Critical Periods; full expression of an ability is facilitated by specific exposures at the proper times, but some potential for development continues for considerably longer time spans (Gottlieb 1983).

Critical Period theory is derived from animal studies of sensory development, especially the development of vision. These studies provide evidence that a critical period, in the strongest interpretation, governs the anatomical and physiological development of the feline visual system. In the case of human cognitive development, the only example of a potential critical period is in language development. Here the weaker interpretation is more appropriate. Language is learned with greater ease by the young, that is, by toddlers and preschoolers. Acquisition in later life is possible (as some of us learned in high school French), but the process may be more difficult (Lenneberg 1967), and the product a less well developed formal system, even for the acquisition of sign language (Newport 1984).

As applied to the case of otitis media, the Critical Period theory states that specific auditory experiences are necessary early in life for the full development of the higher mental processes. Since the hearing loss associated with otitis media is variable and almost always mild (Bluestone et al. 1983), the underlying theory would have to be that auditory input must develop. In this view, bouts of hearing loss early in life deprive the child of the required inputs to other functions during the presumed sensitive period in their development.

THE RATIONAL-CONSTRUCTIONIST THEORY

We coin the phrase Rational-Constructionist theory to capture the fact that this theory differs from the Empiricist theory in two fundamental ways. The first way is that infants' minds are not seen as blank slates on which sensory experiences are passively imprinted. This position, like the Critical Period theory, grants the child an initial biological endowment to select organized aspects from the diversity of sensory experience. Selection is guided by mental structures that interpret the environment such that the sensory data are classified, transformed, even altered as they are processed by the child. Unique to this Rational-Constructionist theory is the second fundamental principle that infants and young children have an active role in their own cognitive development, one that involves their seeking out experience to nourish nascent capacities. The child is not given preformed, full-blown knowledge, triggered as soon as a particular stimulus is encountered. The child has available only initial structures that begin the process of assimilating the environment and that determine the kind of experience that must be assimilated to construct concepts of the world.

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Moreover, in this theory, infants are motivated to seek out relevant inputs that will feed developing structures. This Constructionist assumption contrasts with the Empiricist and Critical Period theories that have the infant taking in only that which is presented but doing nothing to search for, alter, or even reject inputs. This formulation follows Piaget (1975); the infant works hard to get an environment that supports cognitive development in domains in which nature has provided some initial preparation. Infants and young children may even create their own environments for cognitive development.

There is a growing body of evidence in developmental psychology to support the Rational-Constructionist position in cognitive and language development.[2] Experiments with infants of very young ages demonstrate that they select sensory input for particular processing and handle the data in an organized fashion. For example, as discussed elsewhere in this volume (see chapters by Strange and Eimas and Clarkson) one-month-old infants do not handle speech sounds as mere auditory signals but as phonemes, units of language which alter the meaning of words. Their performance is akin to adult performance in similar paradigms. Similarly, young infants demonstrate that they understand the coordination of cross-modal sensory data from the eyes, hands, and mouth that indicate properties of real objects such as rigidity or malleability (Gibson and Walker 1984). Finally, young children are motivated, even after succeeding on tasks with trial and error solutions, to generate systematic approaches to problems and to improve their performance (Karmiloff-Smith and Inhelder 1974/5; DeLoache, Sugarman, and Brown 1985). They continue to search for new solutions without rewards, or modelling, or even prompting.

More support for this theoretical position comes from empirical data that demonstrate that a given set of sensory experiences is not absolutely necessary for aspects of cognitive development. One such demonstration comes from the study of deaf children of hearing parents (Feldman, Goldin-Meadow, and Gleitman 1977). These children were deprived of verbal language experience by their biological condition and sign language experience by their parents' commitment to an oral education. In these families, the children lacked sensory experience associated with learning a formal language system. Nonetheless, the children invented their own system of manual communication. Their system was based on elements available to them, movements of hands, body, and face, but used in a novel symbolic fashion. The system was functional; it was possible for their families to respond to the gestures appropriately (Goldin-Meadow and Mylander 1984),

[2] An extensive review of the empirical support for this position can be found in Gelman and Brown (1986).

and for the researchers to translate them into an understandable form. Furthermore, in both structure and content, the early gestural system was reminiscent of the earliest stages of verbal language learning in young hearing children. They talked, or rather gestured, about small objects before large objects and actions before attributes.

Another illustration comes from the study of blind children. It has often been assumed that concepts of the visual world derive from the visual inputs and that the child learns the meaning of words in particular, and language in general, by having someone point to objects or actions and label them. It follows that a blind child should not only have trouble learning language, she should be especially at risk when it comes to learning vocabulary terms related to vision, e.g., *look* and *see*. Her knowledge of objects should be limited to those features that are defined by touch or by sound. A dramatic set of demonstrations to the contrary are present in Landau and Gleitman (1985) who found that acquisition of syntax, early vocabulary, and functional uses of language in congentially blind children is remarkably like the acquisition of the same abilities in normal, sighted children. These authors provide compelling demonstrations that Kelli, one of their congenitally blind subjects, came to understand the words *look* and *see* in a fashion similar to sighted children. To explain the preserved abilities, the authors suggest that Kelli substituted the verbal environment for the visual environment, that she used linguistic context to acquire these words. The absence of the presumed sensory requisites did not block development.

This position leads to a very different notion of what constitutes a supporting environment. A supporting environment is not simply that environment with the greatest amount of sensory input of the kind that bears a surface resemblance to the concept. Presumably a supporting environment is one with a diversity of sensory experience. But ultimately, the child must define for us the environment that she needs for optimal development. Our adult preconceptions that vision is necessary to learn about objects beyond the size of our hands or that hearing is necessary to begin a symbolic language system have been severely challenged by the very children whose receptors cannot process such sensory information, but who nevertheless learn.

The Rational-Constructionist position thus makes very different predictions about the effects of otitis media on cognitive and language development. A decrement in the amplitude of auditory stimulation or some inconsistencies in the nature of the input need not interrupt the acquisition of knowledge since the infant can actively search out alternative sources of information or alternative approaches to management of that sensory system. This position does not take the stand that the environment is irrelevant for cognitive development. On the contrary, the environment is fundamental for adequate cognitive growth. However, the features of the environment which are critical for cognitive development are not obvious. Input need not be specific to a single sensory domain. Children may be able to substitute alternative environmental stimulation if the usual input is degraded or unavailable and may be motivated to overcome or to compensate for the special environmental circumstances with which they live. In the research on effects of otitis media, there is no clearly articulated theory of the role of environment. Theorists and researchers must develop such a theory if they are to understand environmental effects. Watching how impaired children cope is one way to start developing such a theory.

Studies of Effects of Otitis Media on Cognitive Development

The Empiricist position leads to hypotheses that the child is vulnerable to even minor disruptions of sensory input. Thus, the studies following this theoretical position would predict a correlation between the severity of otitis, presumably a function of frequency and duration, and developmental outcome. Disruptions wherever they occur during acquisition limit the auditory input and hence the opportunity to learn in multiple domains (Howie 1980).

One study based in part on an Empiricist theory is that of Teele, Klein, and Rosner (1984). Children were selected for study based on an estimate of the severity of their otitis media with effusion. The prediction was that the longer the time with effusion the greater the negative developmental consequences. The theory seemed to determine the interpretation of results. Statistically significant effects of otitis media were found in the high socioeconomic status (SES) group only on three formal test measures. There were no significant effects in the low SES group on these measures. There were also no effects in either SES group on any of the measures apparently derived from a language sample, including intelligibility, the number of grammatical transformations, the mean length of the utterances, or articulation. Yet, the authors did not discuss the complicated patterns of results. The discussion revolved around the positive findings, differences which supported the implicit developmental theory. The lack of any differences in the low SES group and in measures from language samples in both SES groups were dismissed without serious discussion. There was no consideration of the educational or functional significance of these findings. The demonstration of any differences seemed to herald such profound and pervasive effects that the authors alerted pediatricians to the possible need to reconsider medical practice on the basis of these data.

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The Critical Period theory also predicts that children will be vulnerable to the effects of early otitis media. However, the timing and degree of sensory disturbance is deemed crucial to the developmental outcome. Episodes of otitis media outside the critical period should have less impact on the developmental course than episodes within the critical period. If the critical period is between two and four years, the bouts which are restricted to infancy or middle childhood (and leave no physiological damage) should have no lasting effects on language and cognitive skills. Of course, for cognitive and language development it is difficult to guess the length of any critical period. The critical period for language development has been posited to last at least several years, possibly into adolescence (Lenneberg 1967).

There is some evidence to support a Critical Period theory for the development of auditory processing and speech perception mechanisms in humans. Work by Eimas on speech perception (reported in this volume), suggests that early auditory experience may affect the way that speech signals are processed.

However, the evidence for a critical period for higher level cognitive development is less convincing. The otitis media literature frequently assumes that the critical periods for sensory processing are critical periods for cognitive processes as well. The implicit theoretical position is that early sensory experience affects processing mechanisms that in turn impair cognitive processes. The Critical Period hypothesis thus merges with the Empirical position, despite the former's commitment to an innate endowment for a particular behavior. Optimal sensory data is necessary in both theories for optimal cognitive development.

One representative study based on a Critical Period theory is that of Zinkus, Gottlieb, and Schapiro (1978) who wrote that chronic middle ear disease may have particular significance before four years of age, which they posited as critical periods for speech and language development. They hypothesized that developmental, psychological, and educational delays in school age children may represent the residual complications of otitis media in early childhood, due to irreversible changes in a central auditory processing mechanism. Their subjects came from the population of patients attending a multidisciplinary clinic for learning disabilities. They compared children with histories of severe otitis media and matched subjects with histories of mild otitis media on several measures: the history of language milestones, IQ testing, and reading, mathematics and spelling achievement. Children with severe otitis media were reported to have very substantial delays in the acquisition of single words and sentences. These same children did worse than those with histories of mild otitis on many of the subtests of the IQ examination and on reading and spelling achievement tests.

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The theoretical perspective again affected the interpretation of results. Children with histories of severe otitis scored at the population mean for full scale, verbal, and performance IQ. Thus, despite serious language delays, their eventual intellectual performance was solidly average. The group with mild otitis performed slightly above the population mean accounting for the group differences. The authors did not discuss this impressive ability of children with severe language delays to achieve normal intelligence. Furthermore, there were significant differences on only some of the subtests of the WISC-R which the authors attributed to disturbances of auditory processing. However, they explain in a rather *post hoc* fashion why some of the subtests on the performance section of the WISC-R such as visual-motor coordination showed group differences whereas vocabulary on the verbal subsection did not. Later work by this group (Zinkus and Gottlieb 1980), aimed at describing the nature of the presumed auditory processing deficit in the group with a history of early and severe otitis media, seems to suffer from a logical circularity; the diagnostic criteria for auditory processing deficit were never described and it is not clear what were the independent variables for subject selection and how they differed from dependent variables used to describe the nature of the processing difficulties.

The test of the Critical Period theory requires that differential processing resulting from the non-optimal early sensory exposure have life-long consequences. Zinkus, et al. (1978), though open to alternative interpretation, did attempt to relate the early history of language milestones and the later evidence of auditory processing problems as evidence of irreversible effects. The mere demonstration of early differences between groups cannot speak to the issue of irreversibility. In general, a longitudinal design or age dependent cross sectional design allows for the analysis of reversibility or irreversibility. Needleman and Menyuk (1979) tested aspects of phonological development, skills related to the production and comprehension of the sounds in the language, in children aged three to eight years of age. Although there were some differences at all ages, the magnitude of the differences decreased with age. This study suggested that early differences between the otitis media group and controls might not persist after a period of improved health and hearing. Some studies that include a longitudinal data collection analyze each point in time separately and do not test for interactions over time (Schlieper et al. 1985), the additional statistical measures about interactions over time would provide more evidence about changing trends and more evidence about reversibility or irreversibility of effects.

The Rational-Constructionist position predicts that some high level abilities will develop in a rather normal fashion even if auditory input is limited. How resilient a particular cognitive or language

function will be, given repeated bouts of hearing loss, depends, in part, on whether the function in question depends on auditory input alone for its development. We have already seen that the assumption that blind children need to see to develop concepts about the visual world turns out to be in error because the children use their linguistic environment to solve the problem of induction. Similarly, children who are hard of hearing might make use of inputs we have yet to consider. In order to predict how resilient a particular skill will be, we need to know more about the kinds of environments children can use, their proclivities to seek out or create inputs they need to develop specific domains of abilities, and their abilities to compensate in other ways to a less than ideal condition.

There is some evidence of developmental resiliency of high level functions. Hubbard et al. (1985) studied two groups of children with cleft palates, one of whom underwent myringotomy early in infancy and presumably enjoyed improved hearing, and one of whom underwent myringotomy late in infancy or later during the toddler years and presumably suffered from chronic otitis media and conductive hearing loss. They found differences between the groups in articulation but no differences in IQ scores. These data suggest that early sensory experience may be important to some aspects of language function but not necessarily to measured intelligence.

When cognitive development is viewed from a Constructionist perspective, it is necessary to grant the child an active role in the creation of her own environments. On the assumption that she will do this work, we must be prepared in turn to follow her inclinations. Children who suffer from otitis media may gravitate to less noisy environments so as to maximize the ratio of signal over noise (see Davis this volume); similarly, they may prefer one style of conversation over another, such as face-to-face interaction, frequent repetitions, and simplified linguistic style (Menyuk 1980; Horowitz and Leake 1980). Careful attention to what kinds of environments make them comfortable and maximize their performance could provide clues for nonintrusive interventions.

Another valuable research strategy is to study the children with otitis media who develop completely normal cognitive function. Just as the deaf and blind children provided major clues regarding the nature of a development and the kinds of environments which nurture specific skills, similar studies of children with otitis media who succeed at performing well on the skills in question might provide both theoretical and clinical insights into the factors that protect the child from serious consequences of otitis media.

The Rational-Constructionist hypothesis does not predict that all abilities will necessarily develop normally even if the environment is rendered optimal. Severe and protracted cases of otitis media may take their developmental toll. However, the theoretical position focuses attention on the need to know much more about the kinds of experiences that could encourage the child's active participation in her own cognitive development. Further, it focuses attention on the need to consider in detail how different aspects of cognition may be at risk. On the assumption that what counts as input for one capacity need not count as input for another, it is crucial that we analyze the nature of skills that may be influenced by limits in auditory function (Menyuk 1980). Menyuk (this volume) concludes that all aspects of language acquisition are not affected equally by otitis media and, therefore, presumably are not controlled by a single mechanism. Hearing loss might influence the ability to discriminate beginning sounds of words and unstressed functors of sentences such as prepositions and articles, but it need not stop the child from developing the ability to use the rules of the language called syntax (Gleitman and Wanner 1982). Similarly, hearing loss may limit the number of different novel words children can hear and learn but it need not stand in their way of forming concepts. Research designs should include a comparison of abilities, some that we suspect will be spared and some that we suspect will be at risk.

The research strategy just outlined is seldom used in the literature on the effects of otitis media on cognitive development. Instead, much of the research to date has considered intelligence testing or academic achievement. These are useful measures for some purposes, since they offer a quantitative prediction of school performance. However, they are empirically derived measures that were not designed to understand underlying mechanisms or structures of thought. They are particularly problematic in the preschool population where even predictive validity is limited. Thus, the results on IQ or achievement tests do not indicate the locus of any cognitive lesion.

The alternative we propose would be to demonstrate that the variable hearing loss associated with otitis media interacts with the acquisition of key concepts or basic cognitive processes. (See Kagan this volume, for some discussion of this point and the need for new assessments of this type). A direct prediction from the above discussion would be that language-dependent cognitive structures would show an effect of hearing loss whereas language-independent tasks would not. The logic of this research design is to find statistical interactions between groups and tasks. If a history of hearing loss had only general effects such as motivation, then the performance of an otitis media group would be shifted downward compared to controls, regardless of task. If hearing loss had specific effects in specific domains, then performance of an otitis media group would be normal in

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some tasks and below normal in others. It would be important to predict, before testing, the pattern of results to avoid *post hoc* explanations.

A concrete example of this research design would be the comparison of an otitis media group and a control group on tasks of classification versus causal reasoning. Classification appears to be a cognitive skill with dependence on language whereas causal reasoning is a cognitive skill with little relation to language. Let us explain in detail.

In classification tasks, verbal labels seem to serve as a constraint that tells children that the object should be thought of in terms of its categorical membership rather than functions or story themes. If you show a two year old a cup, and label it as such, then when asked to "show me another" the child is likely to choose on the basis of category, another cup. If no such label is used, then the child is more likely to choose on the basis of a thematic relationship, for example, a pitcher or plate or person who can drink, rather than another cup. Waxman and Gelman (in press) showed that normal three-year-old English speaking children used this classification strategy even when the labels were in Japanese, a language they did not know. There were two conditions in their experiment. In one condition, called the "label" condition, children were told that a puppet liked a specific picture object called a "dabootsu," but the term was not defined for them. In the other condition, known as the "instance" condition, it was the puppet who was given the Japanese name (to control for the effects of using a strange word with the children), but the object that the puppet liked was unnamed. The task for the children was to find additional objects that the puppet would like. The children did much better in the label condition than in the instance condition at classifying new exemplars according to class membership.

On the other hand there are many cognitive tasks performed by young children where language seems to play no major role. One is in the development of causal reasoning, one aspect of which is the ability to understand how objects undergo transformations of state via specific instruments. Premack (1976) has developed a non-verbal technique to study what children and non-verbal primates understand about the state-state transformation relationship. The method involves the use of unfamiliar picture sequences. Two of three pictures of this causality sequence are presented and the child's task is to choose, from three candidates, the one that best completes the sequence. For example, the child is shown a picture of a pair of glasses followed by a hammer and asked to choose which picture completes the sequence. The correct answer is obviously a pair of shattered lenses. Since both the reasoning process and the method for assessing it are not language dependent, we would expect otitis patients to be indistinguishable from controls on this task.

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Conclusions

Our suggestion to the research community is to generate specific hypotheses about possible effects and non-effects of otitis media on cognitive development. Much of the research to date seems predicated on an implicit Empiricist position or Critical Period theory that predicts deleterious effects of otitis media and resultant sensory impairment on cognitive development. In its strongest form the Empirical theory predicts the analogue to the dose response curve; the worse the otitis the more serious the effects. The Critical Period theory predicts life-long irreversible changes in auditory processing mechanisms which are often predicted to disrupt higher level functioning in much the same way as the Empirical theory predicts. Studies based on these theoretical positions often minimize complexity of their own results and ignore alternative interpretations of their data. The authors rush to suggest radical interventions such as surgery in order to prevent these sequelae.

We feel that the goal of research on otitis media and cognitive development should be more than just the demonstration of slight group differences on global measures of auditory processing or intelligence quotients. We have offered support for a Rational-Constructionist theory of cognitive development. We feel that this position predicts developmental resiliency under many untoward conditions including some cases of otitis media. The position suggests that a few bouts of ear infection might not suffice to interfere with developmental progress in a biologically prepared and active organism. Of course, there may be deleterious developmental effects under some conditions, presumably protracted or very frequent infections. But the research emphasis under a Rational-Constructionist position would focus on factors that offer protection as well as factors that increase risk and on functions that develop normally as well as those that develop abnormally. The position supports the notion that there is as much to learn from children with otitis who develop normally as from those who develop abnormally.

We strongly support a research enterprise that carefully defines the patient population and documents the severity of illness not only in otologic but in audiometric terms. We also feel that other host and environmental factors should be considered carefully as they interact with the illness and subsequent development. We favor a longitudinal design to determine if short term consequences become permanent. Finally, we recommend the use of hypothesis-driven

measures of cognitive development that assess basic concepts and cognitive process in addition to traditional assessments of intelligence quotient and academic achievement.

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